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# PALLET BOXES AND PALLETIZED CONTAINERS FOR HANDLING AND STORING

# SWEETPOTATOES

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in cooperation with

North Carolina Agricultural Experiment Station

## PREFACE

This report is based on research which is part of a project to develop better methods of commercial storage and handling of sweetpotatoes. General supervision of the work was by Joseph F. Herrick, Jr., Transportation and Facilities Research Division, ARS, and John W. Weaver Jr., Department of Agricultural Engineering, North Carolina State of the University of North Carolina at Raleigh. This report is listed as Paper No. 1869 of the Journal Series of the North Carolina Agricultural Experiment Station.

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Trade names are used in this publication solely for the purpose of providing specific information. Mention of commercially manufactured products does not imply endorsement by the Department of Agriculture over similar products not mentioned.

## SUMMARY

Sweetpotatoes handled and stored in field crates on pallets showed less damage, shrinkage, and decay than roots handled in conventional tub-bottom bushel baskets, in a test made in a commercial storage. The field crates were unloaded at the storage and stacked three pallet loads high by forklift truck. The bushel baskets were unloaded and stacked 12 baskets high by hand, with the aid of chain conveyors, in a separate storage compartment. During the two-month storage period, the temperature and humidity in the two storage compartments were approximately the same. An earlier, small-scale test showed that damage to sweetpotatoes caused by the storage container was greater with bushel baskets than with palletized field crates.

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# PALLET BOXES AND PALLETIZED CONTAINERS FOR HANDLING AND STORING SWEETPOTATOES

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## INTRODUCTION

Of the 30 million or more bushels of sweetpotatoes produced each year in the United States, more than half are cured and stored before being sent to market or used for seed to produce the next crop. Satisfactory curing and storing of sweetpotatoes begins with harvesting of the crop. Injuries produced by harvesting and handling should be healed by curing the roots for 4 to 7 days at 85° F. (2, 12, 13).[1/] After this the temperature should be reduced to 55° to 60° F. and the roots may be held for several months. A high relative humidity should be maintained during curing and storage.

Considerable care should be used during harvesting to keep injuries to a minimum, especially bruises involving crushed tissue which heal slowly (15). Since sweetpotatoes are usually dug with a plow or chain-type potato digger and picked up into bushel baskets in the South Atlantic States, loaded on trucks for hauling, and stacked in storage rooms by hand, considerable opportunity exists for inflicting injuries (9). In addition to the condition of the soil, type of digger and care exercised, the storage container and handling method influence the amount of injury.

The use of pallet boxes or pallet loads of bushel-capacity storage containers for handling and storing sweetpotatoes offers an opportunity to use forklift trucks and other industrial materials handling equipment in larger sweetpotato storages to reduce labor requirements. The use of such equipment can possibly be integrated with mechanical harvesting. Forklift truck handling of pallet boxes and palletized loads is being used successfully with a number of other vegetables and fruits (6, 8, 14).

Tests were initiated to determine if use of pallet boxes or palletized field crates was feasible for handling and storage of sweetpotatoes and if these containers caused less injury to sweetpotatoes than the commonly used bushel basket.

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1/ Numbers underscored and enclosed in parentheses refer to Literature Cited, pp. 22-23.

# METHODS

## 1962 Season

Four types of field-storage containers were tested on a relatively small scale. Two containers were crates which were palletized, one was a pallet box, and the fourth was the standard tub-bottom bushel basket used as a control. Only the basket was lidded.

Centennial sweetpotatoes, dug October 11 and 12, 1962, from a single large field with a one-row, chain-type potato digger, were field graded and carefully placed in bushel baskets and in the two types of field crates. Princeville crates and bushel baskets were filled the first day and Duraboxes and bushel baskets for the pallet boxes were filled the second day. These containers were hauled about 10 miles on an open-bodied truck to a commercial storage house for curing and storing. At the storage, the pallet boxes were filled with roots by carefully pouring sweetpotatoes from some of the bushel baskets.

The pallet box used was a wirebound unit with outside dimensions of 47 x 42 x 25 1/2 inches and inside dimensions of 46 x 41 x 21 3/4 inches. Four pallet boxes were used; each held approximately 820 pounds of freshly dug roots (fig. 1, right). Total height of the pallet stack was 8 1/2 feet.

The wirebound Princeville crate is a sturdy modification of the James crate. This crate has outside dimensions of 16 1/8 x 13 7/8 x 13 1/4 inches, inside volume of 2,570 cubic inches, and held 48 pounds of freshly dug sweetpotatoes. Three pallet loads of 27 crates each were used in the test. The stacking pattern was three rows of three boxes per layer and three layers per pallet (fig. 1, left). Total stack height, including pallets, was 11 feet 3 inches.

The Durabox is a one-piece wirebound field crate with outside dimensions of 19 x 15 7/8 x 10 inches, inside volume of 2,180 cubic inches, and held 44 pounds of freshly dug sweetpotatoes. Three pallet loads of 28 boxes each were used in this test (fig. 1, center). The stacking pattern was three boxes side by side with two rows of two boxes each behind these for each layer (seven boxes per layer) and four layers per pallet. Total stack height was 11 feet 3 inches including pallets.

Standard tub-bottom bushel baskets were used as a control in conventional stacks 12 baskets high. On the average each basket held 54 pounds of roots.

To provide a measure of the condition of the roots upon delivery to the storage house, each root in each of three randomly selected bushel baskets and each type of field crate was examined for loss of skin and bruises. Loss of skin was estimated as a percentage of the surface area of the root. Bruises were scored as an estimate of the percentage of the root damaged. During examination the roots were classified as being in contact with the top or in the top layer, in contact with the sides or bottom of the container, or in the middle and not in contact with the container.

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Figure 1.--Palletized containers, pallet boxes, and temperature recorder, 1962 season.

Fifteen bushel baskets and fifteen of each of the two types of field crates containing roots were weighed before they were placed in the stacks for curing and storing. Five weighed baskets each were placed in the bottom, middle (sixth), and top layers of conventional stacks of 12-high baskets of sweetpotatoes. The weighed baskets were in the interior of the storage stacks and about 50 feet from the other test containers. The two field crates were hand stacked in position on pallets with five of the weighed containers in the bottom layer of the bottom pallet, five in the second layer of the second pallet, and five in the third layer of the top pallet. The four pallet boxes were weighed on truck scales and stacked with a forklift truck. All of the weighed containers were reweighed after storage to obtain a measure of shrinkage during curing and storage.

During curing and storage, air temperatures within the containers were measured with copper-constantan thermocouples and a 24-point recording potentiometer. Relative humidities were measured intermittently (13 times in 13 weeks) with electric hygrometer elements placed within containers.

The commercial storage house in which the test was conducted was of concrete block construction with a concrete floor and consisted of one large room. Heating of the house during curing and when needed during storage was accomplished through the use of hot water pipes imbedded in the floor in one side of the storage area. All test material was located on the side without heating pipes. Ventilation was provided by open doorways and revolving turbine-type ventilators having openings which could be controlled by trap doors.

After 3 months of storage, on January 8, 9, and 10, 1963, the sweetpotatoes were removed from storage. All roots in weighed crates and baskets and 16 bushels of roots from the pallet boxes (approximately 1 bushel each from the top center, bottom center, top corner and bottom corner of each pallet box) were examined for decay, bruising, and shriveling. Roots were removed from containers by locations within container, examined, scored, and weighed. Damage sufficient to exceed U. S. No. 1 grade standards (16) was classified as grade damage. Damage insufficient to exceed these standards, i. e., causing less than 5 percent waste, was classified as nongrade damage. All decaying roots were classified as grade damage, although the presence of field diseases such as scurf was ignored.

## 1963 Season

A commercial-scale test was performed to compare the bushel basket and a larger version of the Durabox. This Durabox had outside dimensions of 20 3/4 x 14 3/4 x 11 1/2 inches, inside volume of 2,711 cubic inches, and held 52 pounds of freshly dug sweetpotatoes. The bushel baskets were filled to an average of 49 pounds net.

The storage was a six-compartment house of concrete block construction with concrete floors. Two compartments were used, one filled with bushel baskets and the other with palletized crates. Each compartment was 48 x 19 feet with a ceiling height varying from 14 to 18 feet.

Heat was supplied through underfloor ducts to four 4- x 12-inch registers at each end of each room. A return air duct was located in the center of each room at floor level. Control of the oil furnace, which supplied heat to all six compartments, was by individual room thermostats and motor-controlled dampers on the supply ducts. Cooling was accomplished by a system which forced cool outside air through the top of the room and was controlled by regular and differential thermostats wired in series connection.

Field graded U. S. No. 1 sweetpotatoes, mostly Centennial variety from two locations, were used in filling the two rooms concurrently. Digging dates were from October 7 to 18, 1963. All roots were dug by tractor-drawn plow. The bushel baskets and Duraboxes were filled with field-graded roots from adjoining rows in the same field on the same day. The containers were loaded by hand on

separate trucks for transport to the storage about 8 miles away. The crates were stacked on pallets placed on the truck beds before loading (fig. 2). Each pallet held 24 crates stacked 4 layers high with 2 rows of 3 crates in each layer. Because of the dimensions of the storage room and the dimensions of the crate, the pallets were placed on dunnage strips to permit crosswise stacking on the truck for stability, front to rear tying, and clearance for the forklift forks.

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Figure 2.--Loading crates on pallets positioned on the truck bed. 1963 season.

After transportation to the storage, the bushel baskets were unloaded and stacked by hand with the aid of chain conveyors. This meant that the baskets were handled several times and were often walked upon as they were stacked to a height of 11 baskets. The palletized crates were unloaded and stacked with a forklift truck (figs. 3 and 4).

Approximately 5,000 baskets were placed in one compartment and 4,400 palletized crates in the other. Some space was lost in the compartment containing palletized crates because of two posts in the storage area, failure to stack according to pattern, and because the boxes were not always stacked as high as room conditions permitted. The palletized crates were stacked three


BN 23793

Figure 3.--Unloading palletized crates at the storage house with forklift truck. 1963 season.

pallets high, i. e., 12 crates high, except at the ends of the compartments where the clearance of 14 feet allowed only an 11-crate stack.

Twenty bushel baskets and twenty crates were weighed and placed in corresponding locations within the two compartments as they were filled. Two of each of the weighed containers were placed in layers 1, 3, 7, 9, or 10, and 11 or 12 at the middle of the end wall and about 10 feet from this point within the stack in each room. No comparison of harvesting, field grading, and container damage was made before curing.

Air temperatures at comparable points within the two compartments were measured during the curing and storage period with a 24-point recording potentiometer and copper-constantan thermocouples. The positions recorded included heights of approximately 1, 7, and 13 feet within the mass of sweetpotatoes and heights of approximately 1 and 11 feet at one end wall of the compartments. Relative humidities were measured intermittently (5 times in 7 weeks) with electric hygrometer units located at heights of 1 and 12 feet at the wall and at a height of 7 feet within the mass.


BN 23794

Figure 4.--Stacking palletized crates in storage. 1963 season.

Sweetpotatoes in the two compartments were graded out from November 16 to December 21 as sales demanded. Test crates were obtained as their locations were reached and placed carefully in the compartment of baskets until the test baskets were reached. On December 20 and 21, all test containers were reweighed, examined, and graded. The grading procedure was the same as that used in the 1962 test except that roots were not separated by location within container.

## RESULTS

### 1962 Season

Average air temperature in all types of containers of sweetpotatoes was 74.2° F. during curing and 64.8° F. during storage (table 1). These temperatures were 1 to 2 degrees above room temperature. Type of container used did not influence temperature to any large extent. Temperatures at the same level (i. e., bottom, middle, or top) in the stacks were less than 2 degrees different on the average whether storage was in bushel baskets or in Princeville

Table 1.--Average air temperature in containers of sweetpotatoes during curing and storage and difference from room temperature at median height, by type of container and its location in stack, 1962 season

| Type of container and location of container in stack | Air temperature[1/] in container and difference from room temperature during-- | | | |
|---|---|---|---|---|
| | Curing period (10 days) | | Storage period (2½ months) | |
| | Temperature in container | Difference from room temperature | Temperature in container | Difference from room temperature |
| | °F. | °F. | °F. | °F. |
| Bushel basket in:[2/] | | | | |
| Top layer --------- | 76.7 | +3.3 | 64.9 | +1.7 |
| Middle layer ------ | 74.5 | +1.1 | 65.2 | +2.0 |
| Bottom layer ------ | 72.7 | - .7 | 63.6 | + .4 |
| Princeville crate on: | | | | |
| Top pallet, side of 3rd layer -------- | 76.9 | +3.5 | 66.4 | +3.2 |
| Middle pallet, side of 2nd layer ----- | 74.0 | + .6 | 65.5 | +2.3 |
| Bottom pallet, side of 1st layer ----- | 71.7 | -1.7 | 62.1 | -1.1 |
| Durabox on middle pallet, side of 2nd layer -------------- | 75.0 | +1.6 | 64.8 | +1.6 |
| Pallet box, 2nd from bottom; measurements made at: | | | | |
| Center ------------ | 74.1 | + .7 | 65.9 | +2.7 |
| Side -------------- | 73.6 | + .2 | 64.7 | +1.5 |
| Bottom ------------ | 73.3 | - .1 | 65.2 | +2.0 |
| Average ------------ | 74.2 | | 64.8 | |

1/ Average of all hourly temperatures.

2/ Test baskets were approximately in the center of the stacks of baskets, i. e., about 10 feet from an outside wall, about 10 feet from an aisle between stacks, and about 50 feet from the stacks of other containers.

crates. At 5 feet above the floor, temperatures in all four containers averaged within approximately 1 degree of one another. Temperatures at the center of one pallet box averaged about 1 degree higher than temperatures at the side of the same box.

The temperature gradient in baskets of roots, from the floor to the top of the stack, amounted to as much as 6 degrees and averaged about 4 degrees during curing and 2 degrees during storage. Figure 5 shows the air temperature in baskets in the top, middle, and bottom layers during the season. Similar data, not shown, were obtained for a temperature gradient in Princeville crates.

During curing, relative humidity averaged 89 percent for all locations measured (table 2). The range for different locations (average of three readings each) was 82 to 96 percent. During storage, relative humidity averaged 63 percent for all locations, and ranged from 56 to 67 percent (average of 10 readings at each location). Differences in relative humidity within and among containers showed no consistent patterns except that the highest relative humidity was located in the center of a pallet box. This would indicate that variations in stacking, exposure, air currents, and possibly other factors such as injury and proximity of decay influenced relative humidity more than

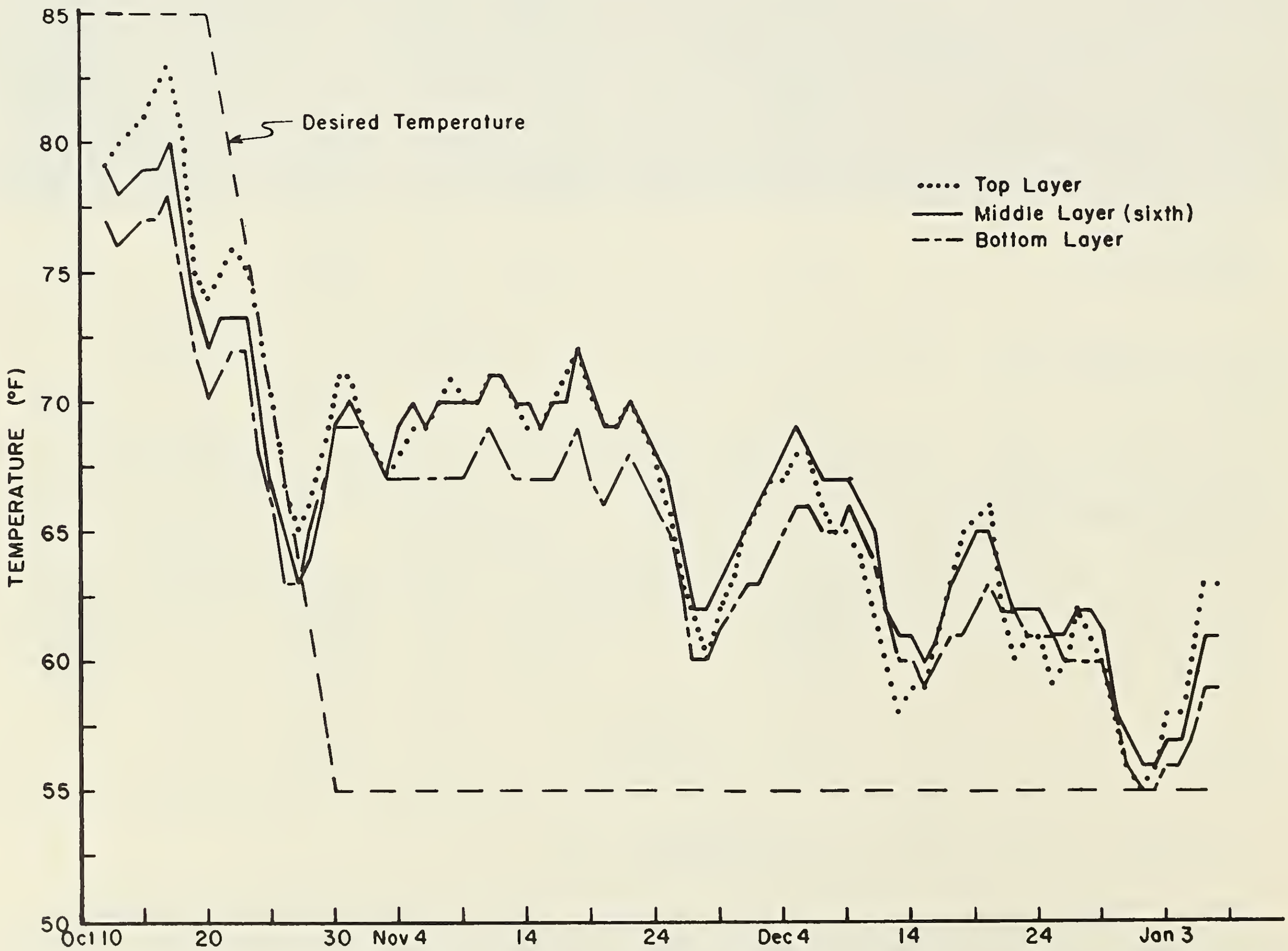


Figure 5.--Average air temperature in bushel baskets of sweetpotatoes stacked in 12 layers--October 10, 1962, to January 10, 1963.

Table 2.--Average relative humidity in containers of sweetpotatoes during curing and storage, by type of storage container and its location in stack, 1962 season

| Type of container and location of container in stack | Average relative humidity during: | |
|---|---|---|
| | Curing[1/] | Storage[2/] |
| | Percent | Percent |
| Bushel basket in top layer | 82 | 63 |
| Princeville crate on top pallet, center of 2nd layer | 94 | 63 |
| Durabox on: | | |
| Top pallet, center of 3rd layer | 82 | 66 |
| Bottom pallet, center of 3rd layer | 90 | 63 |
| Pallet box, 2nd from bottom; measurement made at: | | |
| Center | 96 | 67 |
| Side | 82 | 63 |
| Bottom | 90 | 62 |
| Top | 94 | 56 |
| Average | 89 | 63 |

1/ Based on three readings.

2/ Based on ten readings at approximately weekly intervals.

container. Loss of moisture from the roots, including those not part of the test, during healing of injuries probably helped maintain the high relative humidity during curing.

Regardless of type of container, most of the roots had lost one or more percent of their skin upon delivery to the storage house (table 3). Usually less than 20 percent of the roots showed evidence of bruising. To compare the approximate amount of damage contributed by handling the roots from the field to storage in the three types of containers, it was assumed that little or no damage was inflicted by the container on roots not in contact with the container, i. e., those in the middle. For both bushel baskets and crates, loss of skin was greater for roots in the top or in contact with the sides and bottom of the container than for those in the middle. There was very little difference in the degree of bruising of roots in the various locations in the crates; and in the baskets, bruising was increased over the middle location only in the top. Loss of skin and bruising of roots in all locations in Duraboxes was greater than in Princeville crates or bushel baskets and was associated with injury inflicted during digging. Roots in Duraboxes were dug on October 16, and those in the bushel baskets and Princeville crates on October 15, so a difference in digging conditions is indicated rather than container damage.

During the curing period and the 2 1/2 month storage period, weight losses from the roots averaged 10.3, 10.1, 10.7, and 13.2 percent of the harvest weight for roots in Princeville crates, bushel baskets, Duraboxes, and pallet boxes, respectively. Total damage (grade and nongrade) measured after storage was least for the Princeville crate, with the bushel basket, pallet box, and Durabox next in order (table 4). The percentages of roots exceeding U. S. No. 1 grade standards for decay, bruising, and shriveling were 3.0, 4.4, 8.6, and 7.9 respectively for the Princeville crate, bushel basket, Durabox, and pallet box. Percentages of roots showing nongrade damage were 10.4, 22.1, 26.2, and 25.0 for the Princeville crate, bushel basket, Durabox, and pallet box respectively. A comparison of damage between the bushel basket and Princeville crate is probably reliable, but because of the greater digging damage inflicted on the roots stored in the Durabox and pallet box, a direct comparison between either bushel basket or Princeville crate and the Durabox or pallet box is probably not justified.

Differences between the middle location of each container and the other locations of that container may offer a criteria for judging performance better than the comparison of total amounts of damage in each container. For example, 17.3 percent more roots in the top of bushel baskets showed nongrade damage and 9.0 percent more grade damage than those in the middle (table 4). Roots in contact with the sides or bottom of the baskets were little different from those in the middle. In the two types of crates, however, the difference in total defects due to location within the container was no more than 3.0 percent; this indicates no major influence of position in the container upon quality and presumably little or no loss due to contact with the container. If the comparison of roots in baskets and Princeville crates is considered valid because of reasons mentioned above, handling the roots in bushel baskets increased grade defects slightly (1.4 percent) and nongrade defects noticeably (11.7 percent) more than handling in Princeville crates.

Table 3.--Loss of skin and bruising of sweetpotatoes upon delivery to storage house, by type of container and location in container, 1962 season

| Container and location of sweetpotatoes in container | Percent of sweetpotatoes with: No skin loss | Skin loss, as percent of surface affected, of-- 1 | 2 | 3-5 | No bruising | Bruising,[1/] as percent of tissue affected, of-- 1 | 2 | 3-5 |
|---|---|---|---|---|---|---|---|---|
| Bushel basket: | | | | | | | | |
| Top --------- | 2 | 69 | 23 | 6 | 63 | 31 | 2 | 4 |
| Sides and bottom ----- | 5 | 70 | 20 | 5 | 93 | 5 | 1 | 1 |
| Middle ------ | 20 | 55 | 15 | 10 | 92 | 4 | 3 | 1 |
| Princeville crate: | | | | | | | | |
| Top --------- | 15 | 70 | 12 | 3 | 91 | 3 | 6 | 0 |
| Sides and bottom ----- | 28 | 59 | 10 | 3 | 98 | 2 | 0 | 0 |
| Middle ------ | 35 | 57 | 8 | 0 | 92 | 5 | 1 | 2 |
| Durabox: | | | | | | | | |
| Top --------- | 3 | 76 | 16 | 5 | 84 | 11 | 5 | 0 |
| Sides and bottom ----- | 11 | 81 | 7 | 1 | 85 | 10 | 4 | 1 |
| Middle ------ | 19 | 70 | 10 | 1 | 88 | 11 | 1 | 0 |

1/ Bruising consisted of crushing or breaking of root tissue that extended deeper than the skin.

Table 4.--Percent of sweetpotatoes with grade and nongrade damage after curing and storage, by type of container and location within container, 1962 season

| Container and location within container | Percent of roots in location1/ | Percent of sweetpotatoes with: Nongrade damage2/ | Grade damage3/ | Total | Difference from percent4/ damaged in middle location: Nongrade damage | Grade damage | Total |
|---|---|---|---|---|---|---|---|
| Bushel basket: | | | | | | | |
| Top -------- | 15.9 | 37.0 | 11.5 | 48.5 | +17.3 | +9.0 | +26.3 |
| Middle ----- | 37.6 | 19.7 | 2.5 | 22.2 | -- | -- | -- |
| Sides ------ | 33.8 | 20.4 | 3.2 | 23.6 | + .7 | + .7 | + 1.4 |
| Bottom ----- | 12.7 | 14.9 | 4.0 | 18.9 | - 4.8 | +1.5 | - 3.2 |
| | 100.0 | | | | | | |
| Weighted average --- | | 22.1 | 4.4 | 26.5 | -- | -- | -- |
| Princeville crate: | | | | | | | |
| Top -------- | 15.0 | 11.0 | 3.1 | 14.1 | + 1.8 | - .2 | + 1.6 |
| Middle ----- | 32.6 | 9.2 | 3.3 | 12.5 | -- | -- | -- |
| Sides ------ | 33.2 | 12.4 | 2.9 | 15.3 | + 3.4 | - .4 | - 2.8 |
| Bottom ----- | 19.2 | 8.2 | 2.4 | 10.6 | - 1.0 | - .9 | - 1.9 |
| | 100.0 | | | | | | |
| Weighted average --- | | 10.4 | 3.0 | 13.4 | -- | -- | -- |
| Durabox: | | | | | | | |
| Top -------- | 18.6 | 24.2 | 7.7 | 31.9 | - 1.1 | -1.1 | - 2.6 |
| Middle ----- | 31.2 | 25.3 | 9.2 | 34.5 | -- | -- | -- |
| Sides ------ | 25.5 | 30.3 | 7.2 | 37.5 | + 5.0 | -2.0 | + 3.0 |
| Bottom ----- | 24.7 | 24.4 | 9.9 | 34.3 | - .9 | + .7 | - .2 |
| | 100.0 | | | | | | |
| Weighted average --- | | 26.2 | 8.6 | 34.8 | -- | -- | -- |
| Pallet box: | | | | | | | |
| Top corner - | | 26.0 | 10.4 | 36.4 | | | |
| Top center - | | 24.5 | 4.6 | 29.1 | | | |
| Bottom corner | | 24.0 | 9.5 | 33.5 | | | |
| Bottom center | | 25.5 | 7.0 | 32.5 | | | |
| Average5/--- | | 25.0 | 7.9 | 32.9 | | | |

1/ Based on weight before storage.
2/ Nongrade damage includes roots bruised and shriveled sufficiently to detract from appearance but not sufficiently to be scored below U. S. No. 1.
3/ Grade damage includes roots decayed or bruised and shriveled sufficiently to exceed U. S. No. 1 grade standards.
4/ Calculated by direct subtraction.
5/ Pallet box averages obtained assuming each sample represents an equal amount of sweetpotatoes.

The effect of container location within the storage stack is shown in table 5. For bushel baskets and Princeville crates, grade damage increased from the top layer to the bottom layer. The total of weight loss and grade damage in the bottom layer basket was 15.9 percent as compared to 12.4 percent in the top layer. For the Princeville crate this total was 14.0 percent in the bottom layer crate as compared to 12.6 percent in the top layer. This increase from top to bottom layers in both containers was probably due in part to lower temperatures in the bottom layers, particularly during the critical healing period. The bottom and middle layers of baskets also had the effect of the weight of the other baskets stacked on them. This weight is supported both by the container and by the roots, resulting in further damage to the roots in the top of the baskets in the lower layers when they are put into storage. This may explain why the increase in grade damage in the bottom layer was greater in the bushel baskets than in the Princeville crates.

Table 5.--Percent weight loss and percent of sweetpotatoes with damage after curing and storing, by type of container and location of container in storage stack, 1962 season

| Type of container and location of container in stack | Weight loss | Grade damage 1/ | Total weight loss and grade damage |
|---|---|---|---|
| | Percent | Percent | Percent |
| Bushel basket: | | | |
| Top layer | 9.9 | 2.5 | 12.4 |
| Middle (sixth) layer | 10.1 | 4.7 | 14.8 |
| Bottom layer | 10.2 | 5.7 | 15.9 |
| Princeville crate: | | | |
| Top layer | 10.5 | 2.1 | 12.6 |
| Middle (fifth) layer | 10.1 | 3.1 | 13.2 |
| Bottom layer | 10.3 | 3.7 | 14.0 |

1/ Grade damage includes roots decayed, bruised, or shriveled sufficiently to exceed U. S. No. 1 grade standards.

Sprouts up to about 1/4-inch long were noted after storage of sweetpotatoes in all types of containers in the upper layers of the stack. Sprouts were shorter and fewer in number in the middle layers and none were observed on roots in any of the containers in the bottom layer. These differences in sprout growth are associated with the higher temperatures in the top of the stacks.

## 1963 Season

In 1963, the temperatures during both the curing and storage periods were very similar in the two compartments used in the test (table 6).

Differences in relative humidity were also small. For one reading made during the curing period, the compartment containing palletized crates averaged 85 percent and the compartment containing baskets, 79 percent. For four readings during storage, the compartment with palletized crates averaged 70 percent and the compartment with baskets, 71 percent. Since the differences in temperature and relative humidity were small, they probably had little effect on the final results.

Loss of weight from the roots in bushel baskets amounted to 11.0 percent of the initial weight as compared to 7.3 percent for roots in the crates (table 7). Damage, including decay, exceeding U. S. No. 1 grade standards, averaged 9.1 percent for roots in bushel baskets and 4.1 percent for roots in crates. Damage not exceeding U. S. No. 1 grade standards amounted to 16.6 percent for roots in bushel baskets and 12.6 percent for roots in crates. Altogether, 12.7 percent more roots were lost or damaged by handling in baskets instead of crates.

No estimate was obtained of the effects of stacking, stack height, or position in the storage compartments. A marked improvement in the appearance and grading percentages of the roots stored in crates over those stored in baskets was noted by the research personnel and the packinghouse management when the roots from the two compartments were washed, graded, and prepared for shipment to market.

## DISCUSSION

The test made during the 1963 season was probably more typical of actual conditions and therefore more representative than the test made in 1962. Due to the scope of the test in 1963, labor crews had ample time to get used to filling and handling the crates before test containers were selected. Also, the test in 1962 involved considerable extra handling because the crates were stacked by hand instead of being stacked on pallets in the field and handled with a forklift truck at the storage house.

Based on the 1963 tests, an economic saving due to reduction of losses would result from using palletized crates. Losses from shrinkage and decay have been associated with injury to roots in other studies (10, 13). It has been indicated that the bushel basket contributes significant amounts of injury not only to sweetpotatoes but also to other commodities (5, 7, 9). Exact savings due to decreased shrinkage, decay and damage would depend upon field grading, the intensity of grading when packing for shipment to market, and the prices of the grades being sold. The saving was estimated to vary from 10 to 25 cents per bushel stored. Example: Assume that field grading results in 85 percent No. 1's, 10 percent No. 2's, and 5 percent Jumbos stored. Assume that prices of graded roots after storage are $3.00 per bushel for No. 1's, $1.50

Table 6.--Average air temperature at selected locations in storage compartments during curing and storage of sweetpotatoes in bushel baskets and palletized crates, 1963 season

| Storage compartment and point of temperature measurement | Air temperature during:[1/] | |
|---|---|---|
| | Curing period (8 days) | Storage period (6 weeks) |
| | °F. | °F. |
| Compartment containing bushel baskets: | | |
| Inside wall-- | | |
| Top | 80.4 | 63.3 |
| Bottom | 78.8 | 65.1 |
| Support post[2/]-- | | |
| Top | 81.7 | 64.8 |
| Middle | 78.8 | 65.0 |
| Bottom | 72.7 | 63.9 |
| Average | 78.5 | 64.4 |
| Compartment containing palletized Duraboxes: | | |
| Inside wall-- | | |
| Top | 77.3 | 61.3 |
| Bottom | 73.0 | 64.6 |
| Support post[2/]-- | | |
| Top | 80.2 | 61.3 |
| Middle | 77.6 | 61.4 |
| Bottom | 71.3 | 61.7 |
| Average | 75.9 | 62.1 |

1/ Average of temperatures measured at 6:00 a.m., 2:00 p.m., and 10:00 p.m.
2/ About 10 feet in from inside wall and side wall of room.

Table 7.--Percent weight loss and percent of sweetpotatoes with grade and nongrade damage after curing and storage in bushel baskets or palletized crates, 1963 season

| Container | Weight loss | Grade damage 1/ | | Nongrade damage 2/ | Total damage and weight loss |
| --- | --- | --- | --- | --- | --- |
| | | Decay | Other | | |
| | Percent | Percent | Percent | Percent | Percent |
| Bushel basket | 11.0 | 2.3 | 6.8 | 16.6 | 36.7 |
| Palletized Durabox ---- | 7.3 | .6 | 3.5 | 12.6 | 24.0 |
| Difference -- | 3.7 | 1.7 | 3.3 | 4.0 | 12.7 |

1/ Grade damage includes roots decayed, bruised and shriveled sufficiently to exceed U. S. No. 1 grade standards.

2/ Nongrade damage includes roots bruised and shriveled sufficiently to detract from appearance but not sufficiently to exceed U. S. No. 1 grade tolerances.

for No. 2's, and \$.75 for Jumbos. Assume that nongrade damage is not considered in calculating savings. The differences from table 7 result in the following savings:

| | | |
| --- | --- | --- |
| Weight loss | = .037 (.85 x 3.00 + .10 x 1.50 + .05 x .75) | = .101 |
| Decay | = .017 (.85 x 3.00 + .10 x 1.50 + .05 x .75) | = .047 |
| Other grade damage | = .033 (.85 x 1.50) | = .042 |
| | | \$ .190 |

The saving from reduced losses due to storing in palletized crates instead of bushel baskets is therefore 19 cents per bushel stored.

Other potential areas for realizing savings through the use of palletized crates or pallet boxes for handling and storing sweetpotatoes are container costs and labor costs. A reduction in total long-term container costs is possible if less expensive containers such as cardboard cartons are used for shipping, and field crates and pallets or pallet boxes are reused for a number of years for storage and preshipment handling. The container cost per bushel shipped would be the cost of the cardboard carton, about 30 cents, and the amortized cost of the storage container per bushel shipped per year. Using palletized crates, a \$3 pallet lasting 10 years and 24 field crates costing 55 cents each and lasting 5 years would cost 15 cents per bushel shipped, giving a total container cost of 45 cents per bushel shipped. Using pallet boxes, a \$20 pallet box of 20-bushel capacity lasting 15 years would cost 10 cents per bushel shipped, giving a total container cost of 40 cents per bushel shipped. At present, bushel baskets and Hybrid or James crates often are used

once as field crates and then as shipping containers. The cost of such a container used one year for storage and then for shipment must be incurred for every bushel shipped. This type of container costs about 45 to 50 cents.

No measurements were made of labor savings in the 1963 tests but in an efficient system only the truck driver and a forklift operator would be necessary at the storage house when storing sweetpotatoes. Crews used for stacking baskets often have four to six men. Labor savings through the use of forklift equipment have been demonstrated with other commodities (3, 6, 14).

A number of other observations were made during these tests. Sweetpotatoes stored in bushel baskets are subject to damage in a number of ways not possible with palletized crates. The sweetpotatoes directly in contact with the lid receive damage when initially lidded, when they must share with the container in the support of baskets on top of them, and when the baskets are walked upon as the stacks are built up in storage.

The use of unlidded crates allows a check on workers who are field grading. Baskets are usually lidded when filled. The use of pallet stacks in the storage house allows the possibility of easy selection within the house from various varieties, fields, or qualities of sweetpotatoes stored in the house. Flexibility such as this could be of great advantage in filling specific orders. Because of the interlocking pattern used in stacking baskets, baskets must generally be removed in the reverse order in which they were stacked.

The efficient utilization of storage space is of concern. It is affected by many factors, including the size and shape of the roots, whether the roots are handpacked or dumped randomly, the efficiency of the container (inside volume divided by outside volume required), the shape of the container, stacking efficiency of crates on pallets or pallet boxes in storage, etc. No more efficient use was made of storage space with the palletized field crates in this test than bushel baskets because the clearance required between pallet stacks and the space used by the pallets compensated for the space gained by using rectangular crates instead of baskets. The palletized field crates take about 15 percent more storage space than Hybrid or James crates, which are stacked without pallets. The use of pallet boxes instead of bushel baskets, however, would result in a space saving of about 15 percent. Essentially no saving or loss would result by using pallet boxes instead of Hybrid or James crates stacked without pallets.

Unsolved problems involved with the use of pallet boxes for curing and storing sweetpotatoes are essentially those of getting the roots into and out of the pallet box without excessive damage. Roots can probably be put in satisfactorily by hand from smaller containers if emptied carefully by pouring rather than dumping. This could be done either with the pallet boxes distributed in the field or on trucks or trailers in the field. Emptying sweetpotatoes from the pallet boxes at grading lines may be possible with conventional hydraulic pallet box dumpers. Emptying into water in order to minimize injury probably offers the best solution. Roots stored in bushel baskets are now dumped into water at several packinghouses and it should also be possible to dump the roots from large pallet boxes into water.

Palletized crates or pallet boxes offer possibilities of combining conveniently with other new practices in sweetpotato production and marketing. The use of such containers may well facilitate the development of better harvesters through trends to larger acreages and a need for more reliable and faster harvesting. The advantage of using corrugated cartons for shipping has already been mentioned. Use of palletized crates or pallet boxes for storage containers would also make prepackaging of sweetpotatoes more feasible and shipping on pallets possible. Attractive consumer packaging and reduction of decay through the use of special treatments may well increase demand (1, 4, 11).

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